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ELIMINATION OF DEFECTS ON GLASS-ENAMEL COATING USING LASER RADIATION

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Glass-enamel coatings with pinhole defects repaired using pulse laser radiation are analyzed. It is demonstrated that thermal resistance and acid resistance of repaired coatings are no less than those of coatings without defects, whereas microhardness of coating in a repaired zone is higher than that of the base.

Enameling of metal products frequently produces defects, of which pinhole defects are among the most common ones. One way of combatting these defects is to apply additional enamel coats with subsequent firing [1]. If the number of coats has exceeded 4 or 5 and defects keep emerging, further increase in enamel coating is stopped for fear of losing resistance to thermal shock, and defects are repaired by mechanical means, such as golden filling, tantalum screws, etc.

We investigated a method for eliminating pinhole defects using laser pulse radiation. It was shown in [2] that laser radiation generated by a Kvant-15 set (laser based on yttrium-aluminum garnet with Nd, $\lambda = 1.06$ μm) with laser pulse duration 1.5 msec, and pulse energy 2.5 J, power density $7.5 \times 10^4 - 1.3 \times 10^5$ W/cm^2, and pulse frequency 10 Hz produces local fusion of a pinhole defect on a cold substrate. This is related to self-organization of the microstructure of glass-enamel coating under the effect of radiation as a consequence of formation of laser-induced thermocapillary waves by means of modification of surface tension of the melt, when the mechanisms of diffusion, temperature conductivity, and kinetic viscosity in the melt approach each other. In doing so, a special microstructure is formed on the site to be repaired with rings of diameters from 30 to 100 μm.

Steel samples 2 – 10 mm thick covered by one to three coats of enamels UÉS-300 and No. 261 [3] were investigated. Artificial defects were repaired using repair enamel grades UÉS-300, No. 261, and 301-3p. Samples with repaired sites were tested for thermal resistance, microhardness, and acid resistance. The results of testing coatings for acid resistance are given in Table 1.

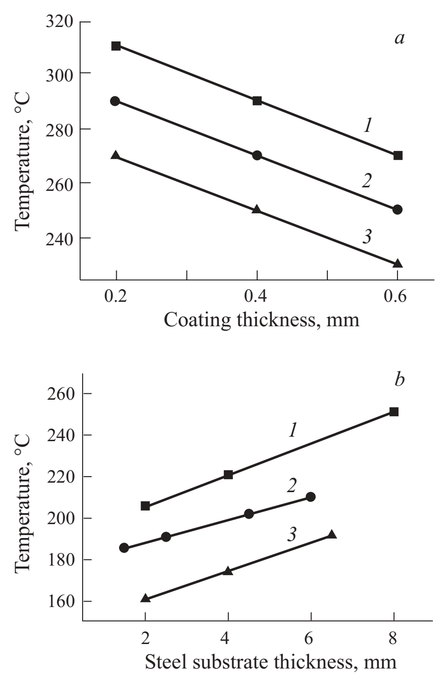

Fig. 1. Dependence of thermal resistance of repaired coating UÉS-300 on coating thickness (*a*) and steel substrate thickness (*b*): *a*) substrate thickness 10 mm; *b*) coating thickness 0.6 mm; repair enamel: *1*, *2*, and *3*) enamels 301-3p, No. 261, and UÉS-300, respectively.

TABLE 1

Enamel UÉS-300 (base)	Repair enamel	Chemical resistance in boiling 20.24% HCl,* mg/cm^2
1	–	0.06
2	UÉS-300	0.10
3	No. 261	0.11
4	301-3p	0.08

* Surface area of contact of coating with acid 38.5 cm^2, treatment duration 48 h.

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Thermal resistance was tested on steel samples of size 50 × 70 mm and 10 mm thick. Each sample was divided longitudinally into three sectors, and 1, 2, and 3 enamel coats were deposited on each sector. The effect of the substrate thickness with coating thickness equal to 0.6 mm was tested on samples of diameter 70 – 85 mm. The tests demonstrated that the tendency known in the enamel industry of thermal resistance decreasing with increasing coating thickness and growing with an increasing substrate thickness holds here. Insignificant discrepancies in the testing results (Fig. 1) are accounted for by different shapes of the samples. It is notable that in the case of complete peeling off of the main coating in heat-resistance testing the repaired sites were the least damaged. The coatings repaired with different grades of repair enamels have higher thermal resistance.

The microhardness of a repaired site (Fig. 2) significantly depends on the type of the main coating and the repair enamel. It can be seen that on repairing a site on enamel UÉS-300 with repair enamel No. 261 the microhardness is significantly higher than on repairing these defects with the same enamel. The same is true of enamel No. 261. In any case, the microhardness of the repaired site is higher than that of the enamel base and reaches a maximum level in the center of the repaired site. This effect is presumably related to the fact that different enamels intensify diffusion processes in the melt, and the thermal effect of laser radiation leads to certain evaporation of low-melting components, which enriches the melt with silica and produces a hardening effect.

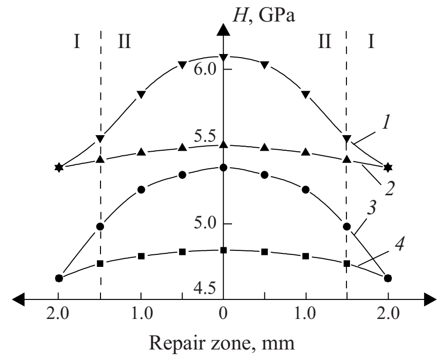

Fig. 2. Distribution of microhardness H in glass-enamel coating (*I*) and on repaired site (*II*): *1*) base coating UÉS-300, repair No. 261; *2*) base and repair coating UÉS-300; *3*) base and repair coating No. 261; *4*) base coating No. 261, repair coating UÉS-300.

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